Radioactive Waste Management

Review of investigation techniques relevant to the geological disposal of radioactive waste

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Radioactive Waste Management (RWM)

Our mission is to deliver a geological disposal facility and provide radioactive waste management solutions

- **Wholly-owned subsidiary of NDA** (since April 2014)
  - Company size circa 100 staff
  - Budget currently around £20 million per annum
- **Roles and Responsibilities**
  - Higher Activity Waste management – essential so that packaged waste is suitable for eventual disposal
  - Tasked by Government to deliver a ***Geological Disposal Facility*** (GDF)
  - Within the GDF siting process we are currently at the stage of Geological Screening of England, Wales and Northern Ireland
  - Commission research and interact with other organisations internationally to support our work

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Waste to be managed for geological disposal

The inventory of higher activity radioactive waste and materials to be managed in the long term through geological disposal comprises:

- High Level Waste
- Intermediate Level Waste
- Low Level Waste not suitable for LLWR
- Spent fuel
- Plutonium
- Uranium

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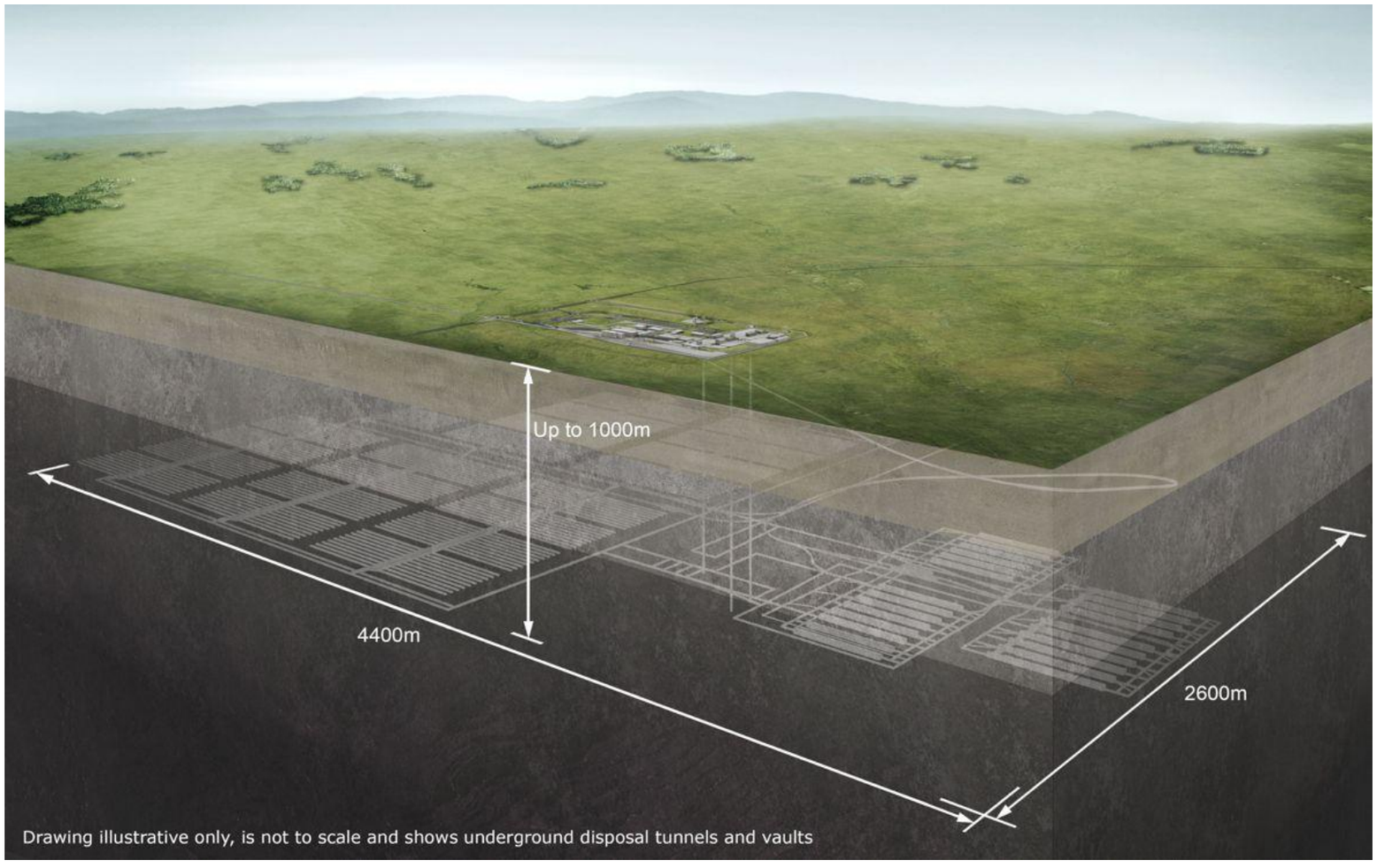
Geological Disposal Facility



- Current preference is for a single facility to accommodate all wastes (co-location)
- Under human management until closed (>100 years)
- After closure, safety provided by engineered barriers and geology
- In long-term safety relies on geology
- Between 200 – 1000 m below surface

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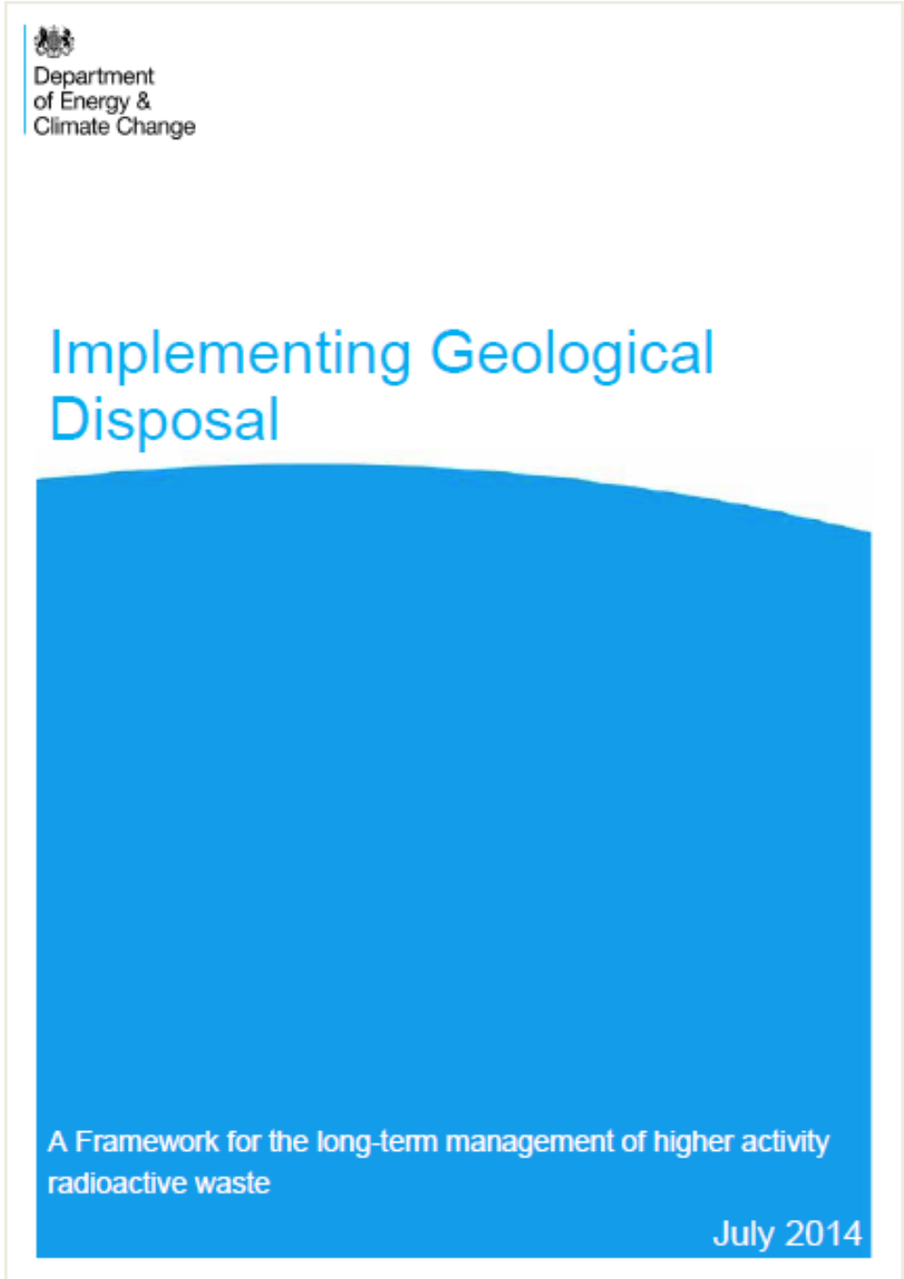
2014 White Paper: *Implementing Geological Disposal*

- A White Paper which sets out the UK Government's framework for managing higher activity radioactive waste

- An 'enabling' document which addresses many issues that stakeholders have raised

- Sets out a clear plan and timescales to address some remaining concerns and help communities participate



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Siting process

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The Site Characterisation Challenge

- Strategic objectives:
  - *…..in a way which **avoids unnecessary impacts** on the safety case for the long-term protection of people and the environment;*
  - *…..based on **sound science** to meet the information requirements for geoscientific understanding need for the safety case;* and
  - *…..in a **cost effective** manner that makes appropriate use of the available technical and managerial resources.*
- Information requirements and parameters that we need to measure to support the design and safety case.
- Suite of reports (2006 – 2013) assessing the techniques available to:
  - Acquire;
  - Model; and
  - Interpret the data.
- Undertaking a review of these techniques.

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Scope of techniques review

Data Acquisition:

- Surface-based geophysics;
- Borehole drilling;
- Drilling fluid tracers;
- Geophysical logging & Wireline testing;
- Hydrogeological testing;
- Geomechanical properties;
- Groundwater sampling & analysis;
  - *Colloids, microbes & organics;*
  - *Inversion of multiple geophysical data sets; and*
  - *Rock properties relevant to radionuclide migration.*

Interpretation & modelling:

- Geology;
- Hydrogeology;
- Hydrogeochemistry;
- Geotechnical;
- Thermal;
- Radionuclide transport; and
- Biosphere.

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Surface-based geophysics

- New airborne AFMAG (Audio Frequency Magnetics) a plane wave frequency domain electromagnetic survey method.
- Rotary or fixed wing operations.
- Depth of investigation exceeding 2000 metres.

Geotech’s proprietary ZTEM

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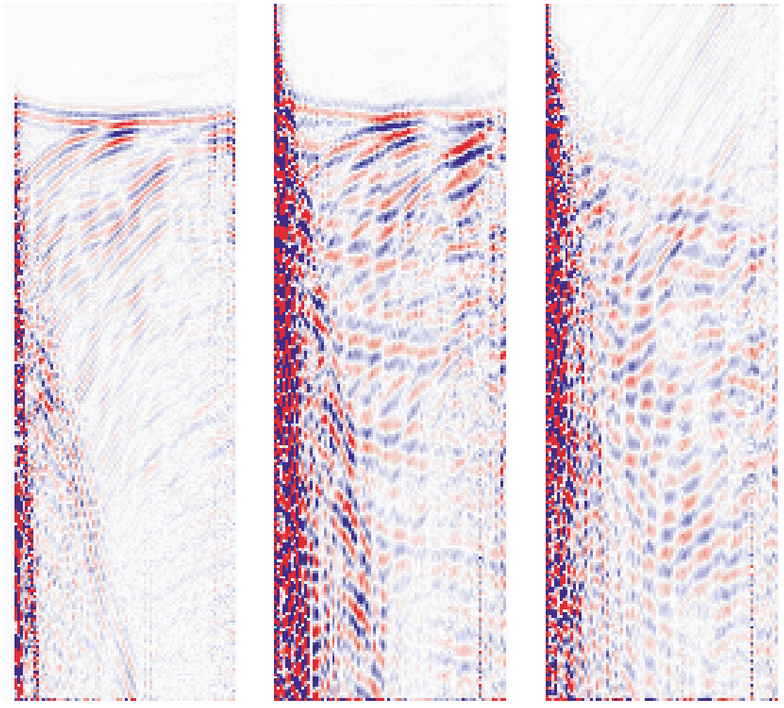
Surface-based geophysics

Seismic reflection moving from 3C to 9C.

- Three component (3C) data acquisition uses one vertical P-wave and two orthogonal S-wave vibrators or one triaxial vibrator as sources.
- Recorded by 3C geophones gives a total of 9 components.



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Surface-based geophysics

Benefits of 9C

- Recording both wave modes captures more information related to rock properties.
- P-waves are influenced by all three bulk rock properties (compressibility, rigidity and density)
- S-waves are influenced by rigidity and density only.
- Combining these observations allows more accurate estimation of subsurface characteristics:
  - lithology identification, fluid discrimination, the ability to image through gas, fracture/stress field characterization & better density estimation.
- Multicomponent provides complementary seismic information for:
  - comparison with conventional P-wave images;
  - AVO results.

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Integrated interpretation of multiple geophysical data sets

- Maturing and consolidating on four approaches:
  - superposition of separately constructed models to search for spatial correlations (e.g. conventional CSEM image co-rendering or immersion within seismic 3D cubes)
  - using structural details furnished by seismic reflection image processing to constrain the inversion of the other methods
  - simultaneous inversion of physically-related datasets for which an analytical or petrophysical relationship exists;
  - structure-coupled simultaneous inversion of different datasets without the need for any analytical or petrophysical relationships
    - Meju (2011)
- Larger oil companies starting to use but far from standard practice.
- One US company which provides just this service.

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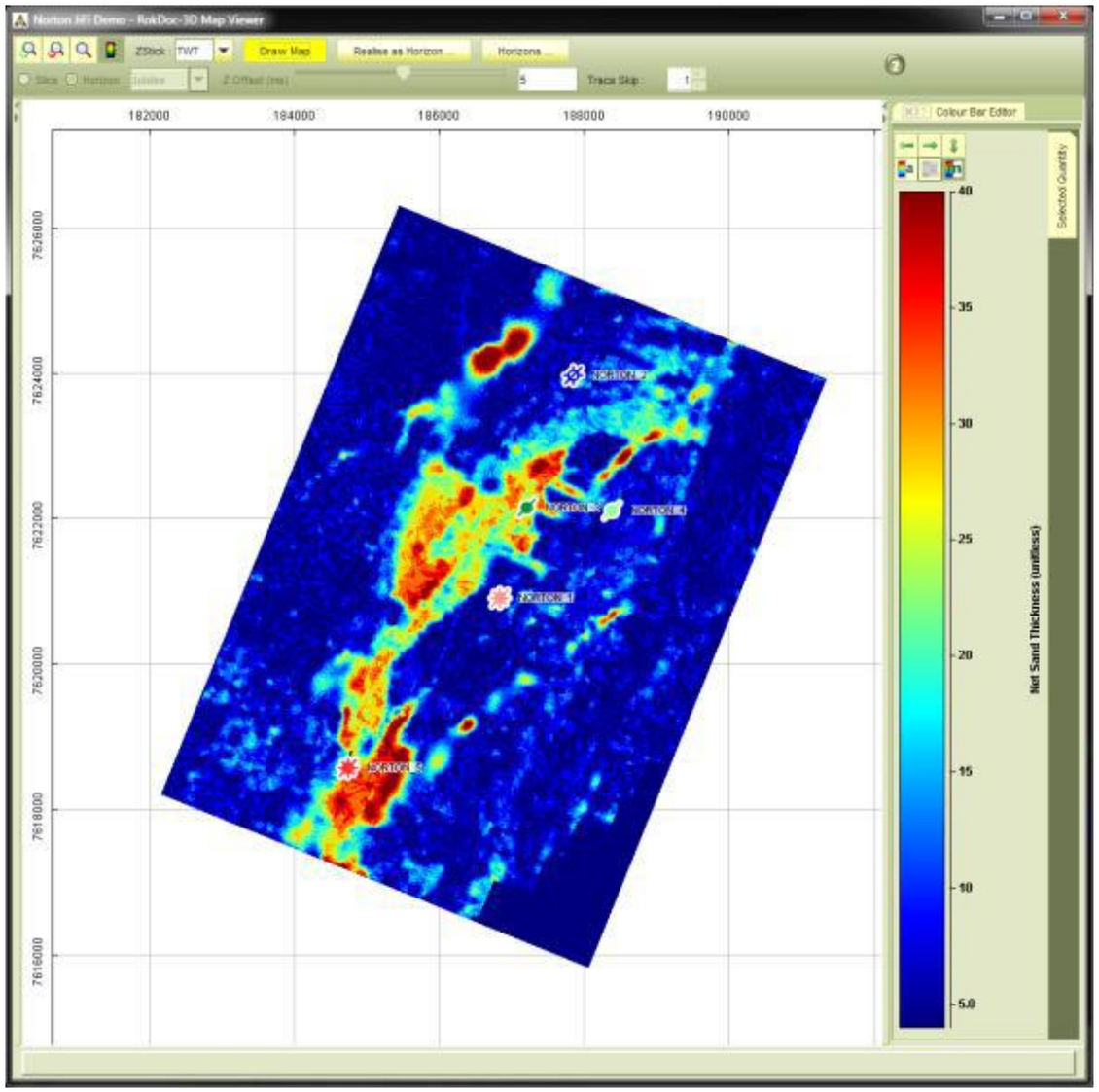
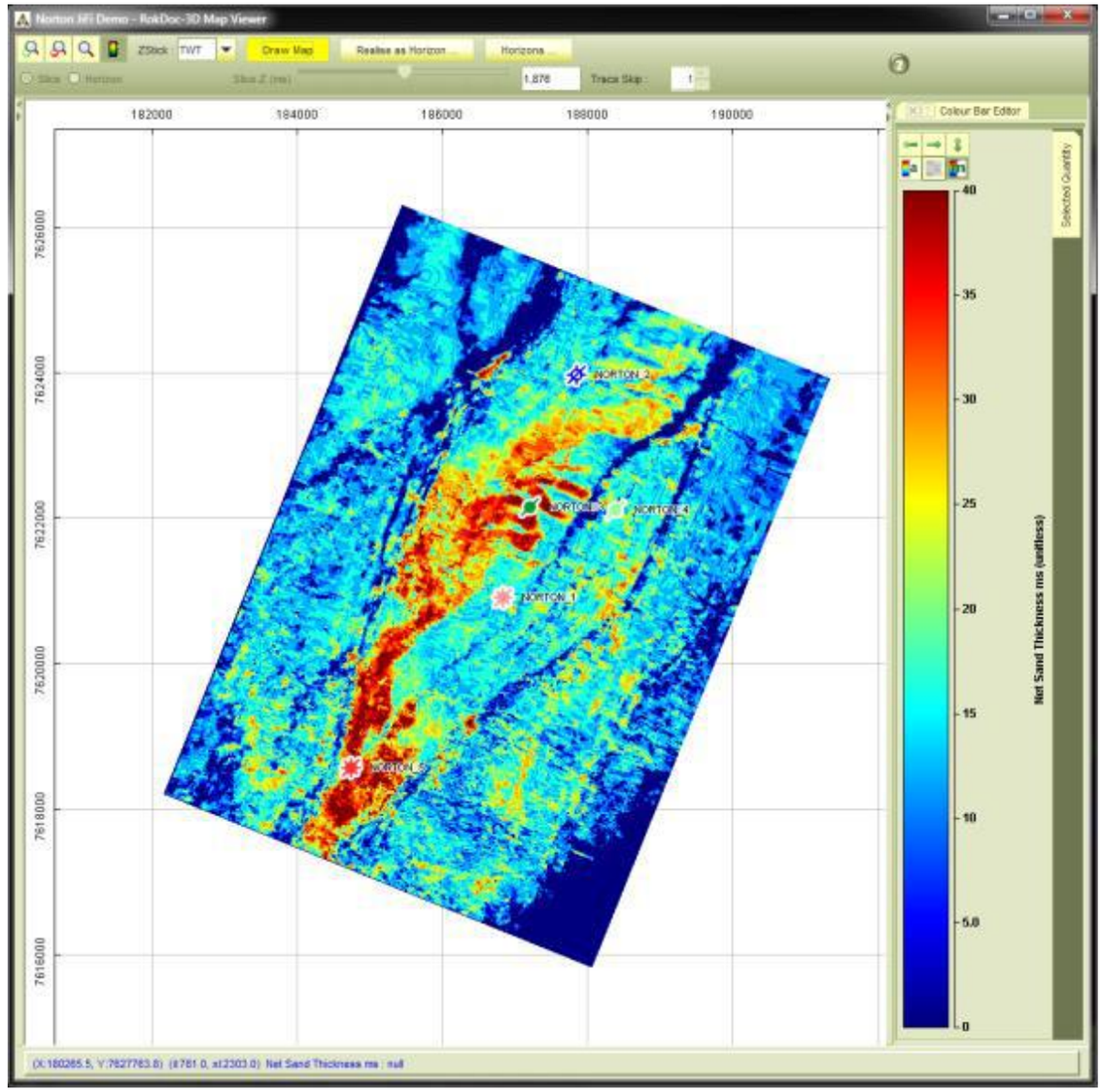
Inversion of multiple geophysical data sets





Net sand derived from the simultaneous inversion [left] and from the joint inversion [right] (Kemper et al 2014). Example from Western Australia.

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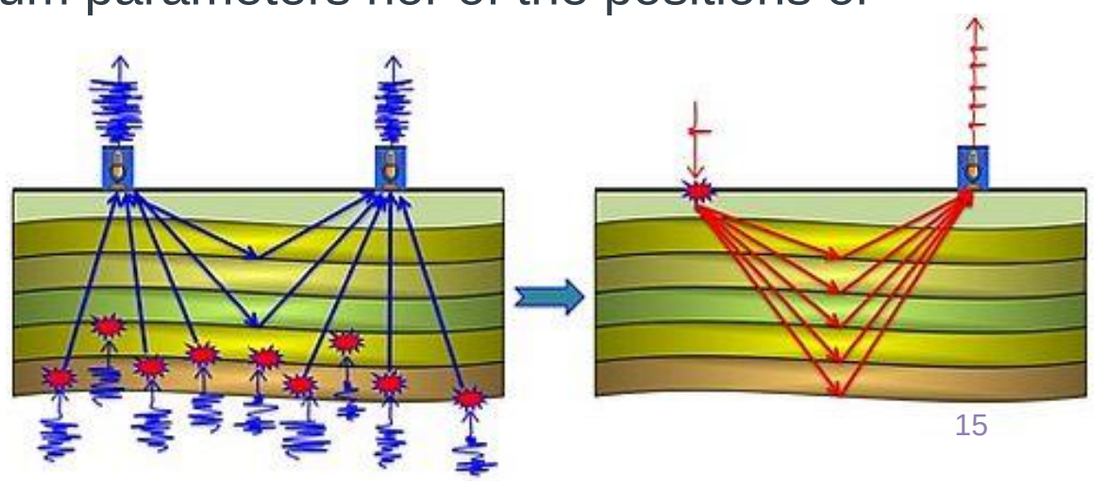
Interferometry and passive seismic

- Seismic interferometry:
  - **new seismic responses** are created by cross-correlating seismic observations at different receiver locations;
  - **virtual sources** are created at positions where there are only receivers;
  - no new information is generated by interferometry, but **information hidden in noise** or in a complex scattering coda, is reorganized into easy interpretable responses that can be further processed by standard methodologies.
  - Wapenaar et al 2010
- Passive seismic interferometry:
  - passive seismic measurements, ambient seismic noise or microearthquake responses
  - converted into deterministic seismic responses.
  - requires no knowledge of the subsurface medium parameters nor of the positions or timing of the actual sources
- Passive seismic
  - Stacking the quiet bits



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Geophysical logging & Wireline testing

- One new technique:
  - Multi-frequency dielectric scanner
    - Variation of the formation dielectric properties – water-filled porosity, water salinity and textural effects
- General increase in resolution, accuracy and pressure rating.
- Oil and gas techniques gradually becoming more available in smaller diameter mining sector boreholes e.g.:
  - Photoelectric factor, elemental yield and resistivity imaging.
- Increasing range of Logging While Drilling (LWD) techniques e.g.:
  - Acoustic, borehole seismic resistivity, formation pressure, sonic imaging and groundwater sample collection.
- Wireline testing
  - Downhole fluid density, groundwater sample collection and testing in low permeability strata.

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Geomechanical & Hydrogeological testing

- Geomechanical
  - Greater confidence in the combined consideration of hydraulic fracturing, overcoring, borehole breakout and drilling induced fractures to estimate *in situ* stress. Wellbore Sonic Scanner data for horizontal stress is also now considered.
  - Advances in Discrete Fracture Network (DFN) modelling.
- Hydrogeological
  - Wireline Formation Testing (WFT) approaches are increasingly replacing traditional Drill Stem Testing (DST) e.g.:
    - Modular Formation Dynamics Tester (MDT);
    - Reservoir Characterisation Instrument (RCI); and
    - Reservoir Description Tool (RDT).
  - Use of deconvolution to normalize pressure and rate data in order to obtain more data to interpret with conventional techniques.

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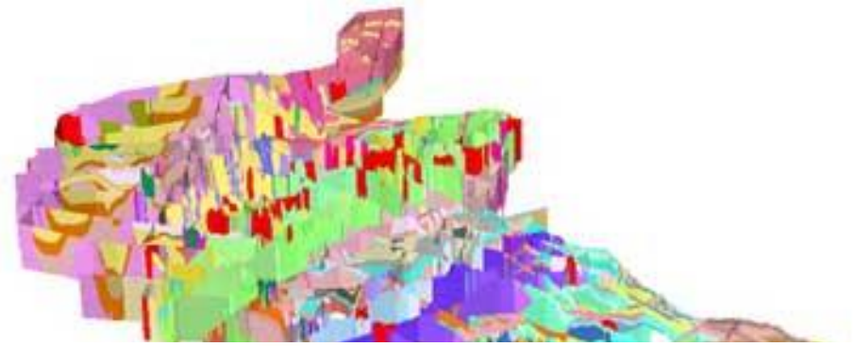
Geology – Interpretation & modelling

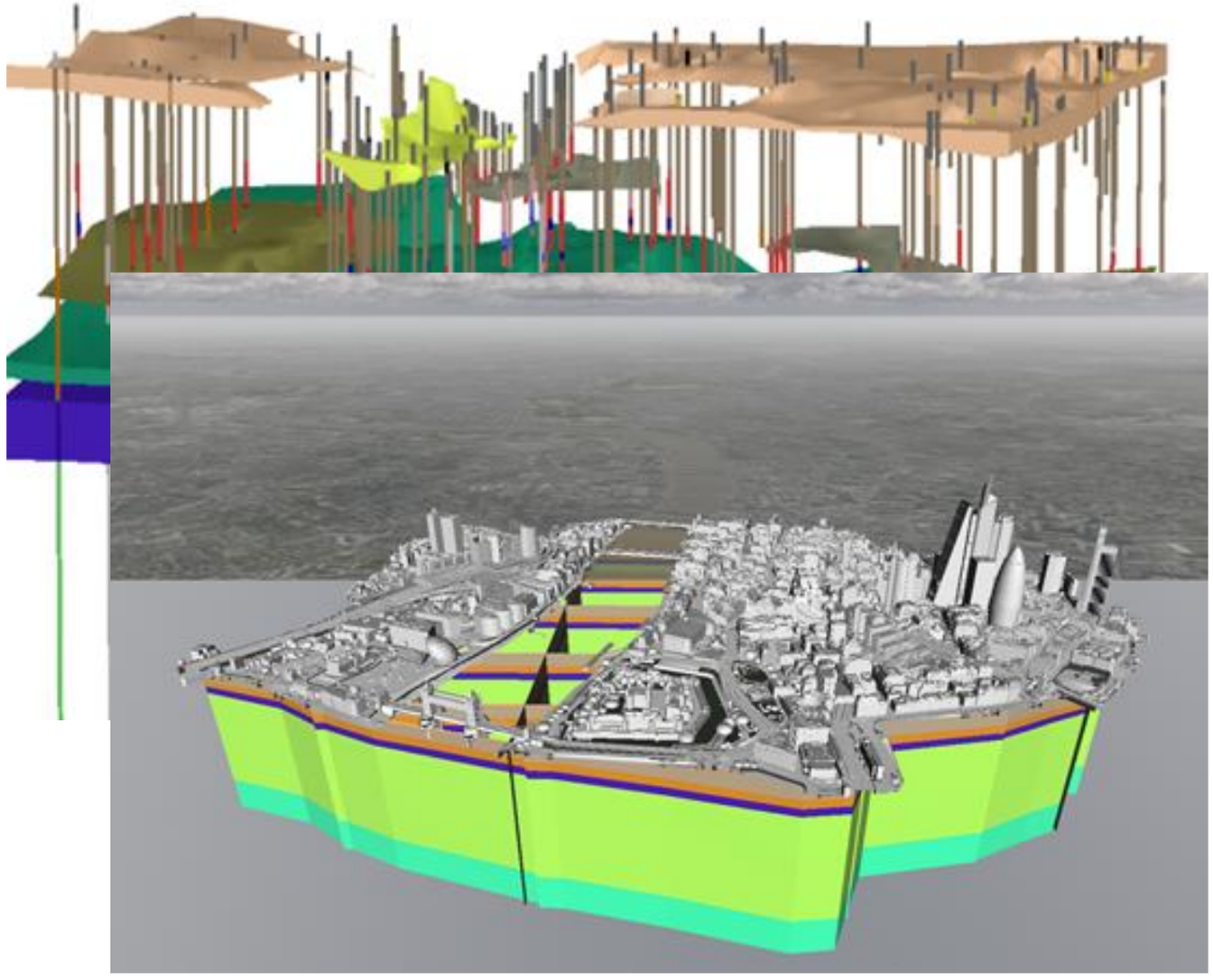
National Geological Models

9 countries or regions in Europe started 3D models since 2010.



Geological modelling tools

focus on interoperability, visualisation and sensitivity analysis.



Building Information Models

digital representations of physical and functional properties of all spatial data considered in the construction process

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Summary

- Increase in resolution and accuracy.
- Greater confidence in techniques due to extended use between sectors.
- Gradual maturation of new and innovative techniques.

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Keeping in touch

- If you have any questions on our preparations siting a GDF or surface-based investigations work you can reach us directly at: Natalyn.Ala@nda.gov.uk or Andrew.Parkes@nda.gov.uk
- You can visit our website at: www.nda.gov.uk/rwm
- If you have any specific questions relating to RWM's work you can contact GDFenquiries@nda.gov.uk
- For regular updates on the National Geological Screening exercise please subscribe to our e-bulletin news alerts at: http://www.nda.gov.uk/rwm/subscribe

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